Superconducting Magnet Program

RHIC Operations Support

Spin Program Support

S&T Committee Program Review

RHIC II (e-cooling) Projects

eRHIC Design Study

Finances

Summary

Peter Wanderer, DOE review, July 25, 2006
Acting Head, Superconducting Magnet Division

RHIC Program Support

Run 6: no repairs to magnets, bus work, or leads.

Six-year average: ~ 1 failure/yr in magnets, bus work, or leads
No systematic problems emerging.

A large inventory of superconducting magnets:

- ~ 300 8cm dipoles
- ~ 400 8cm quadrupole/sextupole/corrector units
- 96 13cm IR quadrupoles
- 24 10cm IR dipoles
- 12 18cm IR dipoles
- 12 Siberian snakes/spin rotators (48 helical dipole units)

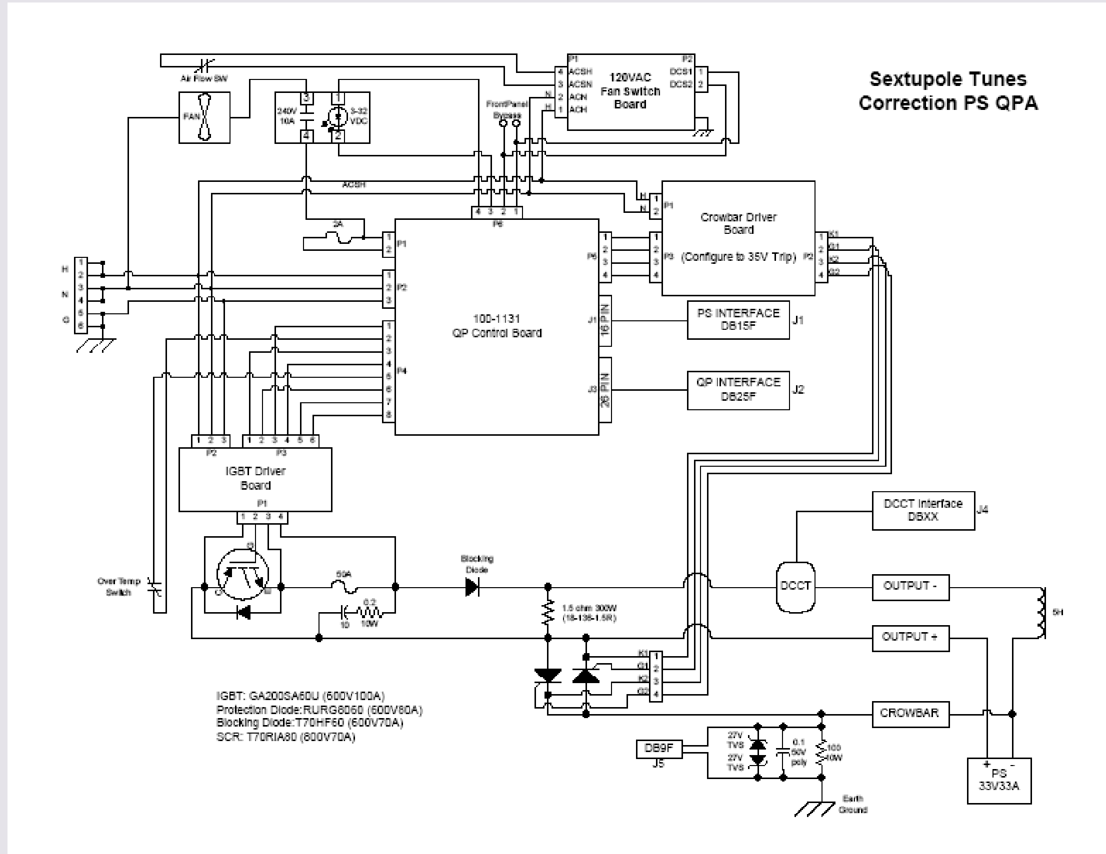
RHIC Program Support

- Quench protection/magnet power supply system integration and fault diagnosis
  - Checkout immediately after a cooldown (just before run)
  - 3 AM, as needed
  - Initiate, monitor warmup to room temp.
- Electronics for revised sextupole circuits (next slide)
- General magnetic measurements – FY06
  - helical dipoles during a slow ramp (mentioned later)
- Shutdown manpower – FY06
  - Cable installation in tunnel

RHIC Program Support

Magnet Division is building 26 Quench Protection Assemblies (shown) and working on the quench detection circuit.

Project will increase sextupole tuning flexibility by increasing number of independent circuits.



This is a “typical” shutdown project.

RHIC Program Support

Cryo Test Facility

RHIC magnet good reliability

+

Effort to maintain cryo test facility

⇒

Decommission stations for testing magnets in cryostats (Magcool)

+

Simplify stations for testing cold masses.

Magnetic field measurement & other control computers: upgrade PC operating systems to meet computer security requirements

Spin Program Support

- AGS Cold Siberian Snake installed March 2005

  (Full list of Run 6 improvements in Thomas Roser's talk.)

- Magnet Construction Issues:

  Complex geometry (variable pitch helix)

  Complex correction coils (made using "direct wind" CAD/CAM)

  Large aperture, high field (20cm, 3T)

  No cryogenic infrastructure $\Rightarrow$ low heat leak, cryo-coolers

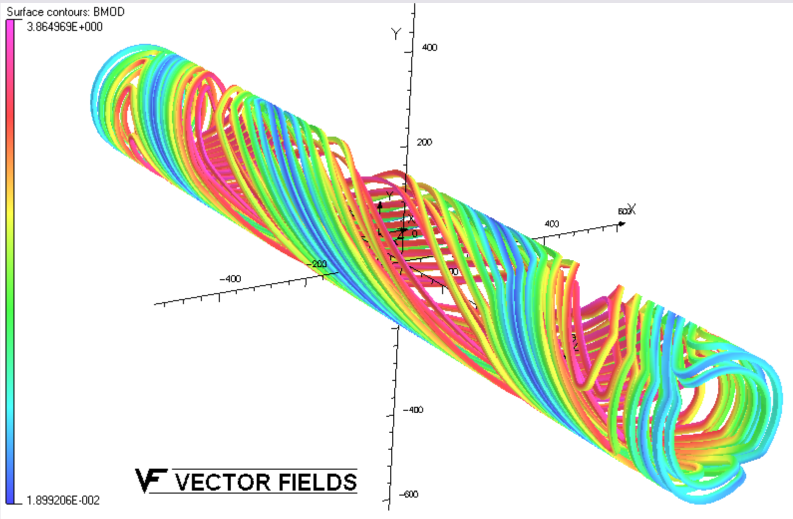
  AGS beam loss induced quenching

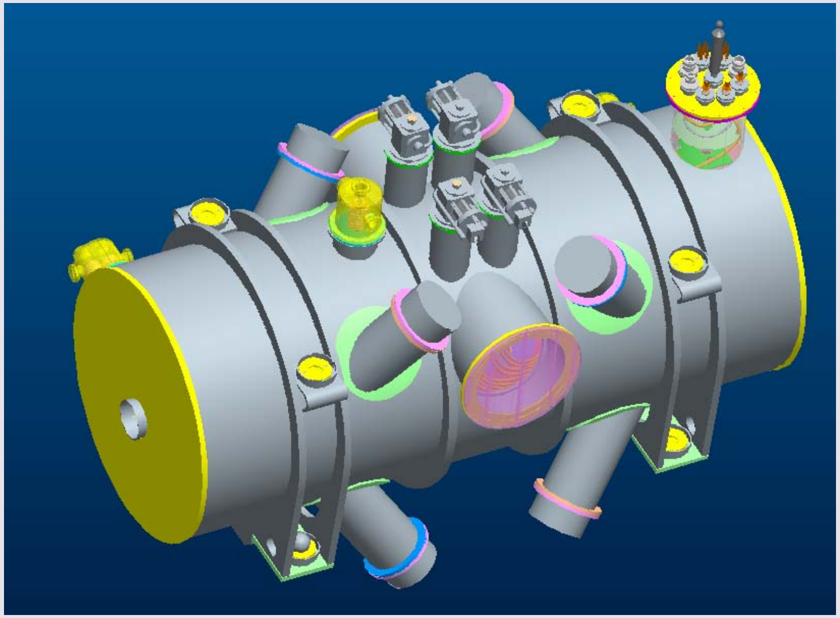
  No prototype

- Improvement, Run 6 vs. Run 5: Polarization 47% -> 65% + luminosity increased a factor of 3 $\Rightarrow$ figure of merit (FOM) $\mathcal{L}P^4$ increased a factor of ~ 11

AGS Cold Snake Design

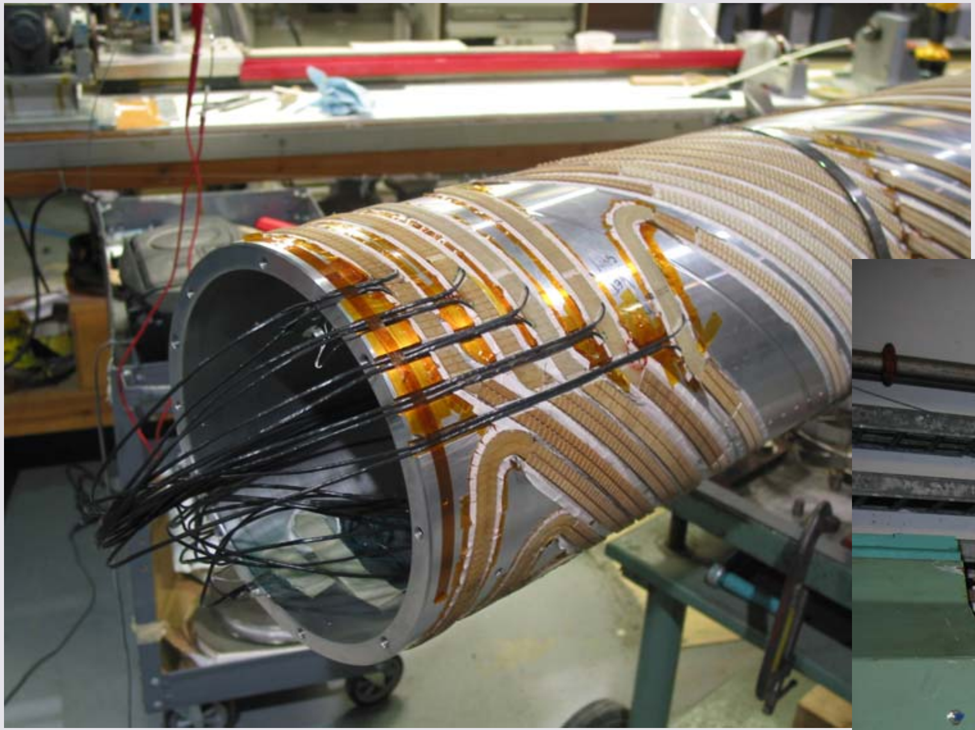
Magnetic design software integrated with mechanical design and machining software ⇒ rapid interaction with accelerator physics group.





ProE 3D design software

AGS Cold Snake

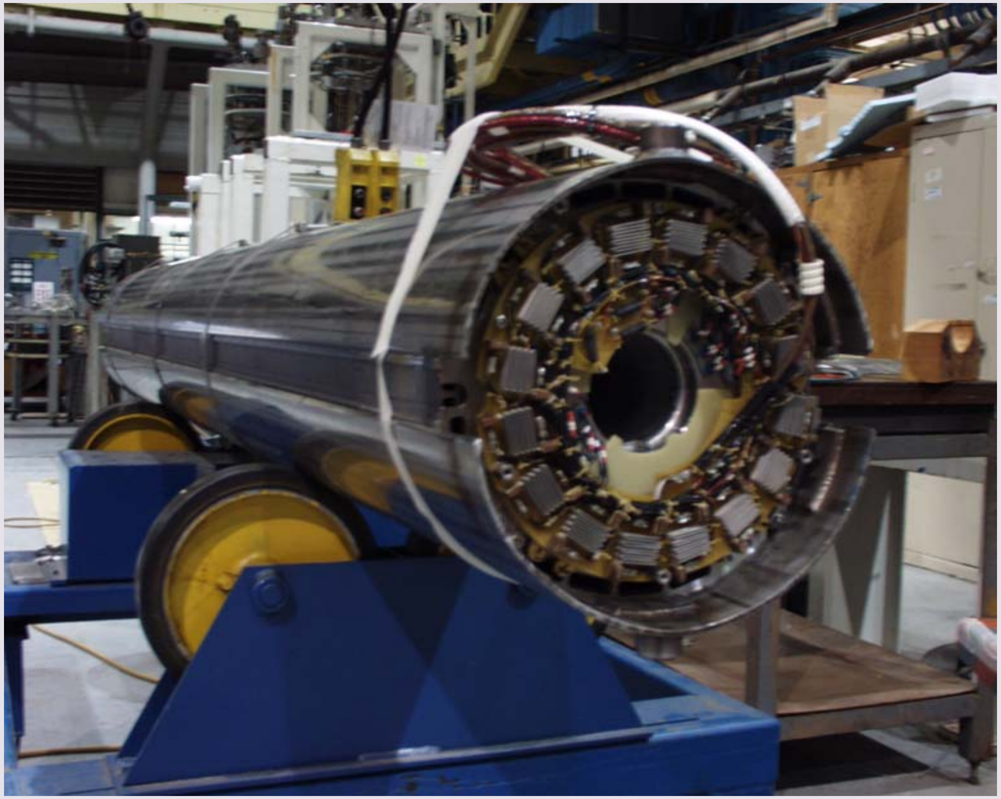


One of two nested coils

Installed in AGS ring

Additional Spin Program Support

- Construction, test of helical spares – one left-hand, one right-hand, in JFY06.
- Magnetic field measurements *during* the ramp
  - Increased operational flexibility
    (original plan: DC only)
  - I_{op} ~ 300 A
  - Ramp at ~ 1 A/sec
  - Use existing measuring equip.
  - 2D, DC analysis probably sufficient



S&T Committee Program Review

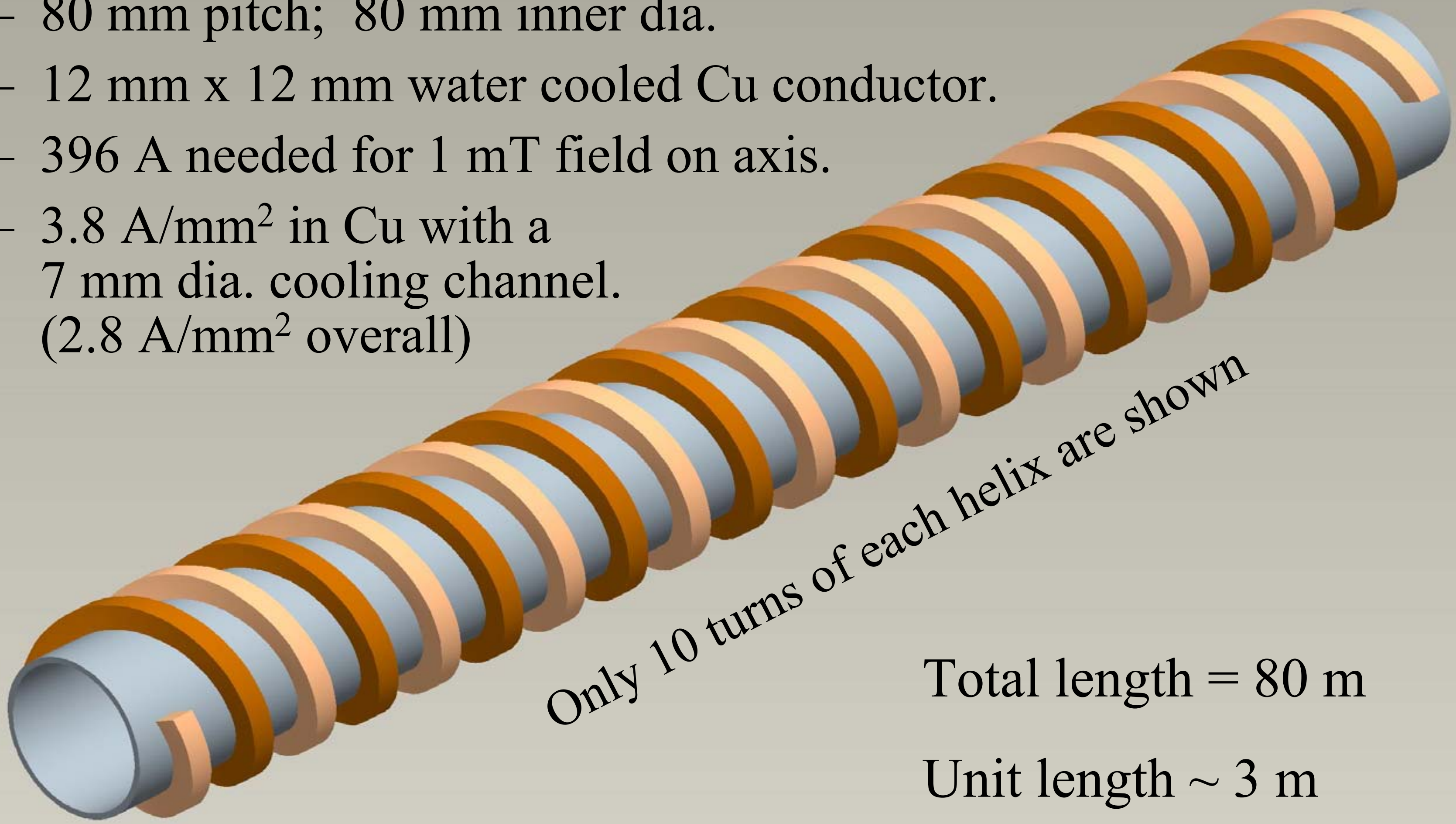
- Review of the role and size of the Magnet Division by members of the BSA Trustees' Science and Technology Committee, magnet experts outside BNL, BNL senior staff, at the request of Sam Aronson, completed last month.
- "In summary, we were impressed with the Division's contributions to superconducting magnet technology and especially the development of the direct wind technique, creative application of high temperature superconductors to accelerator magnets, and superconducting materials R&D."
- "….unique to BNL … important to accelerator science…"
- "We also recognize the Division's critical role in the operation and maintenance of the RHIC magnet system."

RHIC II (Electron Cooling) - Undulator

- Major change during FY06:
  - Prior approach: transverse cooling of ion beam with superconducting solenoid, 2 T < B < 5T.
  - Present approach: transverse cooling with resistive undulator, B ~ 1 mT.

Undulator Parameters

- Two helices, half pitch apart; equal and opposite currents.
- 80 mm pitch; 80 mm inner dia.
- 12 mm x 12 mm water cooled Cu conductor.
- 396 A needed for 1 mT field on axis.
- 3.8 A/mm^2 in Cu with a
  7 mm dia. cooling channel.
  (2.8 A/mm^2 overall)



Total length = 80 m

Unit length ~ 3 m

Undulator Tolerances, Modeling

- Undulator tolerances:
  - Angular deviation of e^- beam (avg. over 1 period) < 5 μrad
    $\Rightarrow \int B_x\, dz < 1 \times 10^{-6}$ T•m; same for B_y
- Undulator modeling:
  - Analytic and finite element models
  - Random and systematic errors
  - Conclusion: for the middle of each 3 m section, the limit on angular deviation can be achieved with reasonable construction tolerances.
  - Errors from ends (80 m / 3 m) ⇒ dipole correctors at ends
- Study shielding needed to block earth's field, stray fields

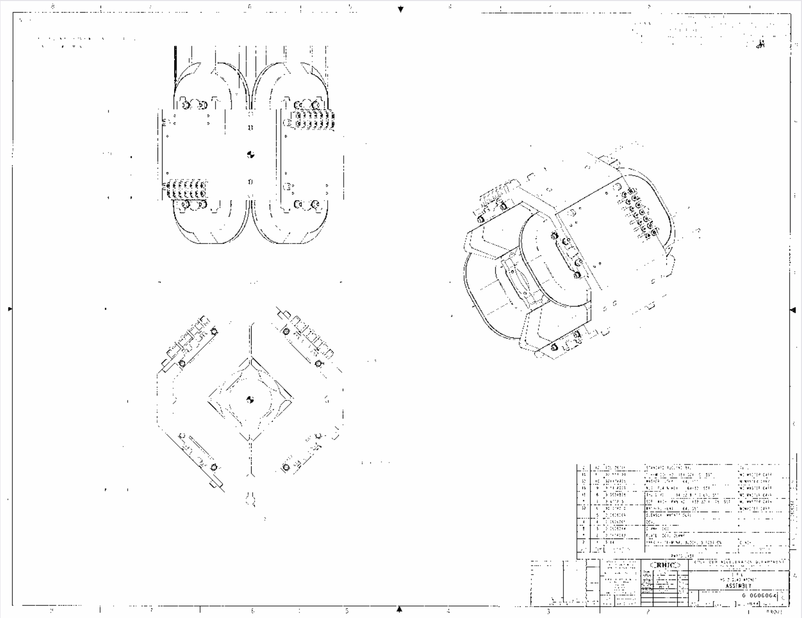
Undulator – Computed Field on axis

RHIC II – R&D ERL

Measure magnets for R&D Energy Recovery Linac

7 Dipoles, 28 quadrupoles

- Prototype quadrupole
  - Due at BNL ~ mid July
  - Stringent requirements on absolute accuracy of ∫G•dl, ∫B•dl, field alignment, magnetic center measurements
  - Modify existing RHIC rotating coil
- Prototype dipole
  - Due at BNL ~ mid August
  - Hall probes



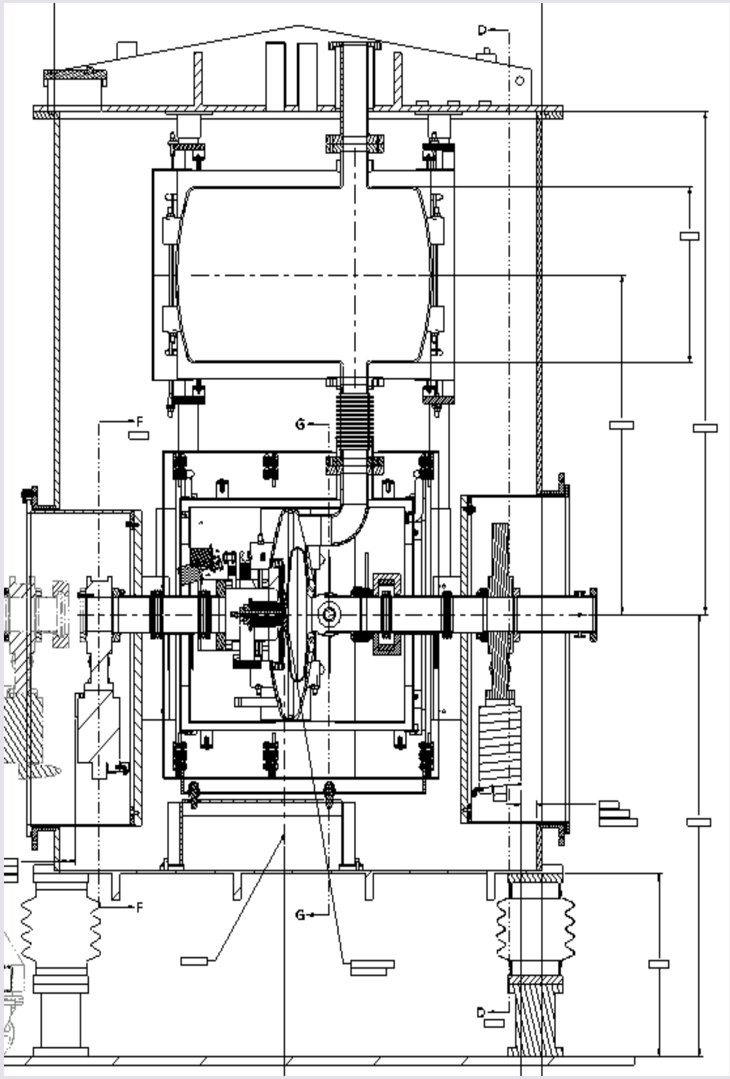
L_{yoke} = 128 mm, bore = 60 mm

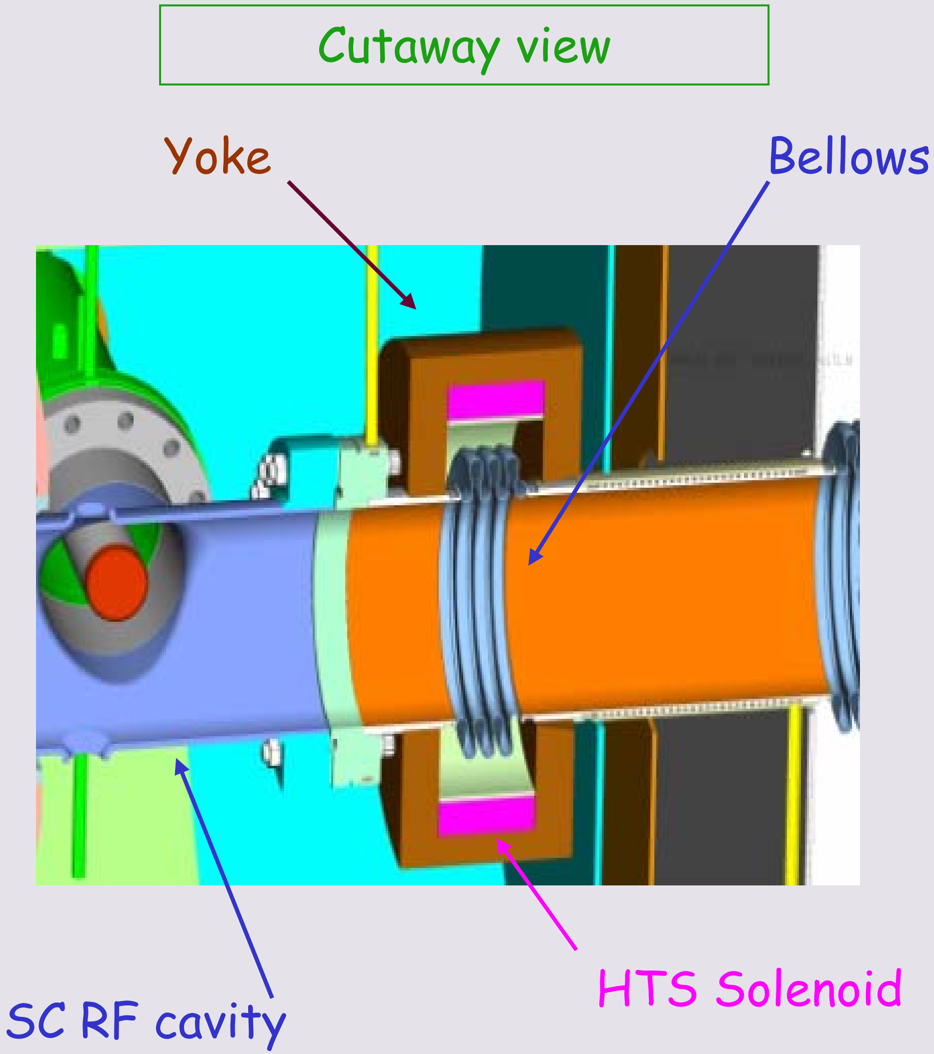
G= 4 T/m, 6.4 A max.

RHIC II – HTS solenoid for electron gun

- First use of HTS in an accelerator
  - HTS = high temperature superconductor, LTS = low temp….
- Focusing solenoid near SC RF cavity:
  - Larger current density, better coil placement $\Rightarrow$ SC solenoid
  - Relaxed operating temperature requirement $\Rightarrow$ HTS, not LTS
- Successful design, test of RIA magnetic mirror fragmentation quadrupole $\Rightarrow$
  - Design utilizing a complex superconductor (J_c varies with θ)
  - Coil construction with a brittle material
  - Operation with new quench propagation characteristics
- Solenoid integral field requirement: $\int B_z^2\, dz = 0.1\ T^2$ mm
  - L ~ 100mm, coil radius ~ 100 mm, I < 50A, ~ 10,000 A turns
- Status: magnet design complete, expect coil to be wound and tested at 77 K by the end of FY06.

RHIC II - HTS solenoid for electron gun





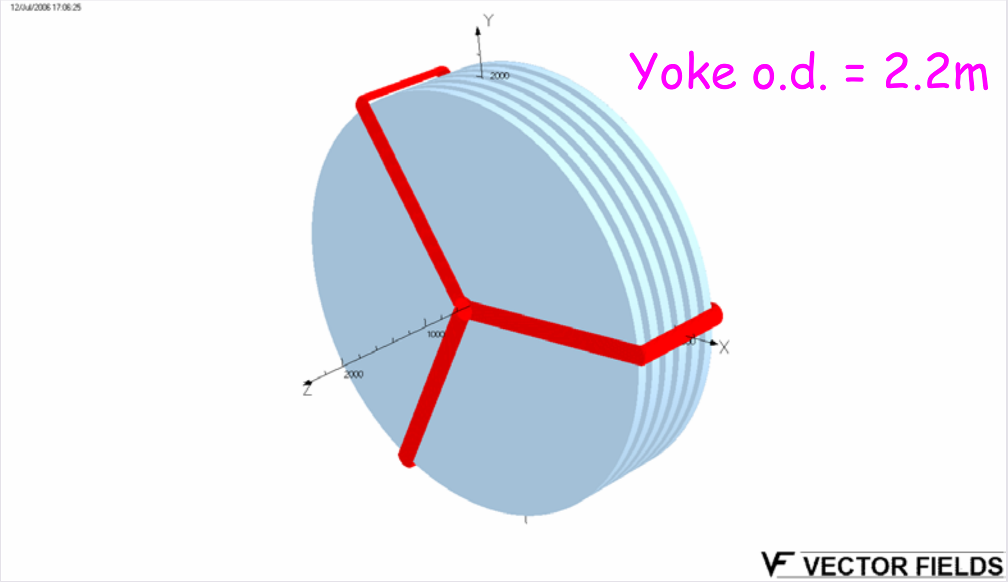
eRHIC Muon Detector Design Study

Muon detector magnet – new concept:

Resistive toroid with *bundled* coils (3 shown here)

Yoke segmentation, longitudinal and radial, optimizes field for muon detection.

Concept still evolving



Each coil encompasses the *entire* length of the yoke ⇒ more space for detector, cheaper to build and operate

Also work on:

Original IR optics

Beam separation magnets

Magnet Division Support from CAD

	FY02	FY03	FY04	FY05	FY06	FY07
NP program magnet support	$4,740	$5,350	$5,874	$5,805	$4,931	$6,100
FTE's	26.5	28.5	29.0	29.0	21.0	28.2

We assume that the RHIC support program will remain at this level of effort for the foreseeable future.

This represents ~50% of the Magnet Division's total activity.

Summary

- RHIC program support requirements maturing (as is the machine):
  - Magnetic measurements are becoming more subtle
  - Magnet technology is becoming more complex
- RHIC magnets very reliable thus far - no major repair role to date.
- No major production tasks anticipated in the near future. We have moved into an R&D environment, specializing in unique magnets (direct wind, HTS, helical).
- Support of RHIC II:
  - Undulator design and error analysis (resistive)
  - ERL magnet measurements
  - Focusing solenoid in ERL electron gun R&D (HTS)
- Support of eRHIC
  - Conceptual design of muon detector magnet
  - Conceptual design of IR, beam splitting magnets
- Planning on a constant level of effort for NP programs.